STAT

THE RADIOSONDE METHOD (Chapter VIII in 'Aerology')

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## CHAPTER VIII

## THE RADIOSONDE METHOD

### No 1. THE BASIS FOR THE RADIOSONDE METHOD

The radiosonde method has a series of advantages in comparison with other methods of investigating the upper atmosphere. Differing from the method of balloon soundings, according to which the results of soundings may be obtained only after finding the instruments, the results of measurements from radiosondes are known (either heard or recorded) at the moment of the ascent of the instrument.

The independence, in obtaining data, from the return of the instruments permits successful ascents of radiosonde apparatus in polar regions, on the seas and oceans (from vessels or islands), in desert areas and so forth. This insures the regular investigation of the free atmosphere in these regions up to high altitudes not accessible to other types of soundings. Besides, radiosondes can be used under all weather conditions.

In addition to the determination of pressure, temperature and humidity, wind measurements can also be made during the ascent of radiosondes: by means of theodolite observations when the radiosonde itself is visible, or by radio directing-finding or radar equipment during periods of limited optical observations (during fog or cloudiness or at night).

Finally, supplementary equipment permits the determination of the height of the lower and upper limits of cloud layers, icing conditions, vertical movements and other factors.

In this manner, with the aid of the radiosonde apparatus, it is possible to make many kinds of the most important aerological measurements which, together with other advantages, brought about the rapid development of the radiosonde method within the last years.

The radiosonde method consists of attaching an instrument (the radiosonde) to a balloon filled with hydrogen and releasing the balloon. Meteorological recording instruments in the sonde control, by signals, a light short-wave transmitter. Upon ascent, the radiosonde automatically transmits coded signals corresponding to the readings of the recording instruments. By receiving these signals on the ground and decoding them, the values of meteorological elements at various altitudes are obtained.

In addition to attaching radiosonde apparatus to balloons filled with hydrogen, radiosondes may also be attached to aircraft, aerostats or other flying machines.

In contrast to the meteorograph the radiosonde, besides having recording devices for meteorological elements, has a coding device for transforming the data into characteristic signals, as well as a radio set. The latter includes a transmitter, usually for shortwaves (KV) or ultrashortwaves (UKV), a broadcasting device and a power supply.

The distance of operation of the radiosonde is about 150 to 200 kilometers, with 1.5 to 2 hours of continuous operation.

For the measurement of meteorological elements, the same recorders as in meteorographs are usually used in radiosondes. However, in several arrangements of radiosondes, other methods of measurement have recently been applied. Thus temperature is sometimes measured by means of a resistance thermometer, (thermistor) and a thermocondenser. For the measurement of humidity, the principle of variations of electrical resistance of some indicator as a function of changes in relative humidity is also used, or the psychrometric method is used.

Radiosonde signals are received with standard or specialized radio receivers. The simplest method of reception is the usual one -- sound -- which doesn't require additional attachments for the receiver. However, the automatic registration of signals has a series of advantages over sound reception.

The advantages of automatic registration are in the impersonality of the registration of the signals received, in a more detailed picture of the structure of the atmosphere (registrations in the form of a meteorogram) and in the ease of processing. In addition to fully automatic operation a combined method of reception (semi-automatic registration) is also used; in this method the signals are received by ear and are registered with the aid of appropriate devices.

## No 2. TYPES OF RADIOSONDE

Depending on several features, all of the existing types of radio sounding apparatus may be subdivided into groups. As a basis of this classification, radiotechnological features such as the wave band used, or the type of the emitted oscillations etc may be adopted; however, the most important feature characterizing the radiosonde as a mechanical and radio instrument is the principle of the coding or ciphering of radio signals.

Coding of radio signals is done by the following methods: (1) number-impulse method; (2) time-impulse method; (3) frequency method.

The number-impulse method is based on the position of the measurement indicator for a particular meteorological element being characterized by a definite number of radio impulses of the same or different duration.

A change in the value of an element is reflected in a change in number, duration and/or combination of signals. In this way this method transmits the signals characterizing the indicators of the instrument by a code analogous to the Morse alphabet: by means of dots, dashes and combinations of dots and dashes.

To record such rea in s, the radiosonde apparatus is provided with a commutator. With this commutator, cepending on the position of the measuring devices, the closing and opening of the circuit of the oscillator is effected, which results in the transmission of signals of various types, with interruptions and pauses between separate impulses. The commutator is actuated either by an air vane revolving in the air flow during the flight of the radiosonde or by a clock mechanism or by the apparatus itself.

The reception of the signals by the above mentioned method is done by sound; however, it is fully possible to apply semi-automatic or automatic registration.

The number-impulse method of coding is applied in radiosonde apparatus of Soviet design: the comb radiosonde apparatus of P. A. Molchanov's system; the commutator radiosonde apparatus of the GGO, the sector radiosonde apparatus of the TsKB.

The time-impulse method of coding is based on the position of measurement indicators being characterized by an interval of time between the initial (control) signal and the working signal, whose onset depends on the position of the gauge. The variation of meteorological elements results in a variation in the interval of time between the control and working signal. According to this method, signals are recorded by means of a coding device, by closing the circuit of the transmitter at moments corresponding to the initial and working signal, or, vice-versa, by interruptions or pauses in the operation of the transmitter.

Temperature

Centigrade degrees

Humidity

Percent

Pressure

millimeters

Figure 159. Arrangement of one of the coding device of a radiosonde apparatus using the time-impulse method of coding.

The coding device applied in this method is constructed in various ways. Thus, for example, (Figure 159) it can be a contact indicator turned by means of a clock mechanism. The indicator comes in contact with the permanent control contacts 1, 2 and 3, situated on the disk, as well as with the indicators of the recorders for temperature t, presspure p and humidity f, each time either closing (or opening) the circuit of the transmitter. The receiving of signals is done by automatic registration. This permits obtaining time intervals according to some scale on a tape, from which the values of meteorological elements are obtained, using data for calibrating the instrument. From Figure 160 it can be seen that in the first cycle the measurement of intervals of time characterizing the value of the meteorological elements is equal to $t_1$, in the second cycle, to $t_2$, differing from $t_1$, and so forth.

Figure 160. Arrangement for recording signals of a radiosonde apparatus using the time-impulse method of coding. a -- initial signal; b -- working signal.

The frequency method of coding is based on the fact that changes of meteorological elements, directly through the recorders or with the aid of mechanical transmission, produce a change in one of the parameters of the oscillating circuit:

capacity, inductance or resistance (for relaxed oscillations). As a result of these variations, either the carrier frequency of oscillations emitted or the modulation frequency, which characterize the given element, change. In this manner, the principal role in the coding mechanism is played by the recorders themselves.

The simplest and most convenient manner of effecting the variations of frequency is a change in capacity of the condenser in the circuit of the oscillator. It may be done by changing the distance between the plates of the condenser, changing the size of the active surface of the plates or by changing the specific inductive capacity of the condenser dielectric. The most widely applied method is the one where the capacity is determined by the movement of one of the plates of the condenser connected to the recorder.

A change in the inductance of the coil may be effected by varying its magnetic flux with the aid of displacing the core which is controlled by the recorder of meteorological elements. According to another method the variations in inductance are determined by the change of position of the measuring device of the meteorological elements, related to the inclusion of a greater or lesser number of turns of the coil in the oscillating circuit.

Changes in resistance may be effected by the recorder itself representing some resistance varying under the effects of changes of the meteorological element (thermistor, hygroscopic film).

The receiving of signals from the radiosonde apparatus, based upon the frequency principle of coding, is according to the method of semi-automatic and automatic registration. In the first instance, the observer tunes the receiver to the wavelength of the signals from the radiosonde apparatus. The tuning knob is connected to the carriage which moves along the length of the drum as its generatrix. The drum revolves by a clock mechanism. The turning of the tuning knob results in a change in the carriage, and in the moment of tuning on the wavelength of the radiosonde apparatus, with the aid of the needle ~~on the needle~~ on the carriage, the observer marks a point on the tape of the drum, the position of which will correspond to the frequency of the oscillations emitted by the transmitter, and, therefore, to the indicator of the recorder ~~receiver~~ of the meteorological element.

In automatic registration, the records of relative changes of meteorological elements are shown on the tape in the form of successive marks as a function of time or pressure without the participation of an operator.

In radiosonde apparatus operating by frequency variations, the basis of the coding device is a low frequency generator connected to the recorders ~~receivers~~. In the latter case, a comparison of the tone heard with the tone of a calibrated sound frequency generator permits the determination of the value of the meteorological element either directly on the scale or with the aid of calibrated curves.

It is not possible to strictly and fully make a classification of contemporary radiosonde apparatus according to coding method because in some systems not one but two methods are applied. This is partly due to the fact that the necessary frequency of measuring meteorological elements is not equal. Particularly, in the transmission of pressure values, continuity of the signals is not essential; it is enough to make measurements by steps with the aid of any kind of contact system. Exactly in the same way, in some systems of radio soundings, measurements of humidity are made less often than measurements of temperature. The latter is the main element, and therefore temperature signals arrive more frequently.

When measurements of an element are made continuously, their frequency must be determined by the demands for a sufficient amount of information needed for the construction of stratification curves of the atmosphere up to limiting altitudes. Taking the mean vertical velocity of the radio sounding apparatus at about 300 meters per minute, it is hardly possible to allow measurements of temperature less frequently than every 15 seconds and measurement of humidity every 30 seconds. Measurements of pressure allow the construction of a curve with sufficient accuracy, if the separate readings occur every 50 to 100 millibars.

Let us now go over to the description of design of radiosonde apparatus produced and used in the USSR, as well as some foreign designs.

## No 3. THE COMB RADIOSONDE APPARATUS OF P. A. MOLCHANOV'S SYSTEM

The comb radiosonde apparatus, belonging to instruments of the number-impulse method of coding, is used in the hydrometeorological service of the USSR. The arrangement of the radiosonde apparatus is shown in Figures 161 and 162.

The manometric tube B serves as the recorder of pressure -- the C-shaped bimetallic plate T, as the temperature recorder and the strand of hair F, as the humidity recorder. With the aid of a lever transmission, each of the recorders is connected with pointer-indicators $T_1$, $B_1$ and $F_1$. Upon the variation of the meteorological element, the corresponding indicator slides along the contacting device -- the triggers $G_t$, $G_b$ and $G_f$.

The main irregularly shaped commutator K and the supplementary commutator $K_f$, brought into revolution by the propeller during flight of the radiosonde, serve as the key or the coding device. They introduce the indicators into the circuit of the transmitter. The positions of the indicators are transmitted by radio signals in the form of dots, dashes and their combinations.

Let us inspect more closely the work of the instrument.

Under the influence of variations in temperature, the shape of the bimetallic plate changes, this is transfered to indicator $T_1$, which slides along the comb $G_t$. The comb consists of five toothed plates 1, 2, 3, 4 and k (Figure 163), attached to each other. The plates are insulated one from another and from the frame by celluloid lining. The teeth of each plate are located on part of the circumference and have one and the same angular size with respect to the axis of revolution of the temperature indicator. The distance between teeth on each of the plates 1, 2, 3 and 4 is equal to three times the angular size of the tooth. The teeth on the assembled comb are so placed that after the tooth of the first plate there follows a tooth of the second, the third and, finally, the fourth plate, and thereafter again a tooth of the first and so forth.

In this manner the comb appears made up of 19 groups or sections having 4 teeth in each.

Figure 161. Diagram of the comb radiosonde apparatus of Molchanov's system (from the temperature comb side).

Figure 162. Diagram of the comb radio sounding apparatus of Molchanov's system (from the pressure comb side).

Each of the toothed plates 1, 2, 3 and 4 of the temperature comb is connected with resilient commutator segments $m_1$, $m_2$, $m_3$ and $m_4$ (Figure 161) by insulated wire. Opposite each commutator segment, on the shaft of the commutator, shaped contacts (star wheels) $n_1$, $n_2$, $n_3$ and $n_4$ (Figure 164) are placed.

number of teeth

number of section

Figure 163. Diagram of the temperature comb.

The number of points of the star wheels is equal to the number of opposite-located commutator segments, i.e., opposite commutator segment $m_1$, connected to toothed plate 1, the star wheel with one point ($n_1$) is located; opposite commutator segment connected to toothed plate 2 -- the star wheel with two points and so forth. The star wheels are so located on the shaft that the teeth that are last according to movement lie along one line. At the ascent of the instrument, the propeller brings into revolution the shaft of the commutator K, whereupon one complete revolution of the commutator shaft corresponds to four revolutions of the propeller shaft. In a full revolution of the shaft of the commutator, the commutator segment connected with toothed plate 1 makes one contact with star wheel $n_1$, the commutator segment connected with plate 2, -- two contacts, and so forth.

The instrument, in series with the transmitter, is included in an anode circuit. The current in the circuit flows as follows: the positive terminal of the battery -- transmitter -- the frame of the instrument -- the bimetallic plate -- indicator -- temperature comb -- commutator segments m -- star wheels n -- axle of the main commutator -- negative terminal of the battery.

With each revolution of the commutator, there is a closing of the circuit through the star wheels, and short signals in the form of dots are sent out. The number of short signals will depend on which tooth of the comb the temperature indicator is located. Thus, for example, if the indicator is located on a tooth of the fourth plate, then the closing of the circuit in a full revolution of the commutator will occur four times, because it will be determined by the four contacts of star-wheel $n_4$ with the commutator segment $m_4$, and the transmission of the signal will be in the form of four dots with a pause (.... .... ....). Therefore, the position of the indicator on the comb is determined by the number of short dot signals received.

Figure 164. Shaft of the commutator with shaped contacts.

Upon a lowering of the temperature and transfer of the indicator downward to the tooth of the first plate, we shall receive signals in the form of one dot with pauses (. . .). A rise in temperature will result in a reverse succession in changes of signals, i.e., after signals in the form of four dots, we will receive signals in the form of three dots, two dots and so forth, because the indicator will be displaced upward to the tooth of the third plate, the second and so forth.

Knowing the position of the temperature indicator prior to release of the radio sounding apparatus and the corresponding value of the temperature, determined by a thermometer, as well as the sensitivity of the temperature recorder (the change in temperature represented by the movement of the indicator through one tooth), it is possible to determine the value of the temperature for each moment of change in signals.

When signals, after an interruption in reception, again are heard, they permit the possibility of determining only the number of the plate on the tooth of which the indicator is located. The section where the indicator is located remains unknown. In order to be able to determine the location of the indicator according to the section number, there is a fifth toothed plate k -- the control plate. Its teeth are so distributed that they substitute for the removed teeth of the temperature plates in the order shown on Figure 163 and in Table 1.

The control plate is connected by wire with commutator segment $m_k$, opposite which star-wheel $n_k$ with seven contacts (Figure 164) is located. During a revolution of the commutator, it makes seven contacts, which results in seven short signals with a pause (....... .......). When after an interruption in the receiving of signals, for example, there successively appear (.. .. ..), and then (....... .......) and later (.... ....), then the indicator is located in the seventh or sixteenth sections, because in those cases the third tooth is replaced by the control contact. To determine in exactly which section, the seventh or the sixteenth, the indicator is located is not difficult, inasmuch as the approximate vertical velocity of the radiosonde apparatus and the mean change in temperature are known.

In a change in pressure, the movement of the free end of the manometric tube is transferred to the pressure indicator $E_1$, which slides along the pressure comb $G_b$ (Figure 162) so that a diminishing in pressure is corresponded by a movement of the indicator downward. The metallic teeth of the pressure comb are interspaced with celluloid between them, so that the end plane of the teeth and of the celluloid are in one plane. Every third tooth is wider than the other two. The pressure comb $G_b$ is connected by an insulated conductor with commutator segment $m_b$, the star-wheel $n_b$ gives a lengthened signal. Star-wheel $n_b$ is located on the shaft of the commutator in such a way that the start of its contact lies in line with the ends of the contacts of the temperature star-wheels.

Since the temperature and pressure combs are included in the anode circuit in parallel, the signals through the shaped temperature and pressure contacts will follow independently from one another upon the closing of the circuit.

When the indicator finds itself on the metallic tooth of the pressure comb the last temperature signal is lengthened, i. e., in place of a dot we will have a dash. For example, the signal (••__ ••__) means that the temperature indicator is found on the third plate and the pressure indicator, on some metallic tooth of the pressure comb. Upon the transfer of the pressure indicator to a celluloid strip, the temperature signal is again short.

Knowing the position of the pressure indicator before the ascent of the radio sounding apparatus and the corresponding pressure value, as well as the sensitivity of the pressure ~~receiver~~ recorder (the change in pressure upon the movement of the indicator through 1 millimeter, it is possible to determine the pressure for those moments when signals are received with the indicator at the start of the tooth, at its center or at its end.

Figure 165. Diagram of the humidity switch.

Two narrow teeth and one broad one serve as a control of the position of the pressure indicator, because the gaps in time in the audibility of pressure signals, according to their size, will follow one another in the same relation. Besides, the change in the number of call signals for humidity from two to three (see below) serves to determine the position of the pressure indicator on the control tooth of the pressure comb.

In a change in humidity, a change in the length of the strand of hair is transferred to the humidity indicator $F_1$, which slides along comb $G_f$, (Figure 162), so that an increase in relative humidity corresponds to a movement of the indicator downward. Comb Gf has 10 teeth, insulated from one another and from the frame of the instrument. Each tooth of the comb is connected by an insulated conductor with a corresponding contact situated on the humidity switch $P_f$ (Figure 161). Besides these contacts, there are three other separately situated contacts: $B_k$, $P_1$ and $P_2$ (Figure 165). The first of these serves to control the position of the humidity indicator, the other two serve for the transmission of preliminary call signals for humidity -- these are connected to the frame of the instrument.

The reception of humidity signals is accomplished with the aid of a supplementary humidity commutator $K_f$ (Figure 162), the shaft of which, with the aid of a worm gear, rotates so that with every 20 revolutions of the main commutator, the humidity commutator makes one full revolution.

A sliding contact R, closing the anode circuit of the transmitter, is situated on the shaft of the humidity commutator. The sliding contact, upon rotation, moves in a clock-wise direction, as is shown on Figure 165, first on contact $B_k$, $P_1$ and $P_2$ and then on contacts 1, 2, 3, 4, 5...10 so that with a full revolution of commutator K, the sliding contact moves over one contact.

The movement of the sliding contact over contacts $P_1$ and $P_2$ gives two long humidity call signals in the form of dashes (or three long signals when the humidity indicator is located on the control tooth of the humidity comb). During this time, temperature signals are not heard.

After the call signals, temperature signals are again broadcast until the sliding contact touches the contact connected to that tooth of the humidity comb on which the humidity indicator is located. At this moment again one long signal will be heard.

Inasmuch as between call contacts $P_1$ and $P_2$, on the one hand, and contact 1 on the other, there is an interval equal to one contact, temperature signals answering to the number of the tooth of the humidity comb will be heard between the call signal and the humidity signal determining the number of the tooth of the comb. For example, the signal (___ ___ ... ... ... ... ___) signifies that the humidity indicator is located on the fourth tooth of the humidity comb.

In this manner, the number of temperature signals counted in the interval between the two call signals and the humidity signal determines the position of the humidity indicator.

Figure 166. A general view of the comb radiosonde apparatus.

Knowing the position of the humidity indicator at the moment of ascent of the radiosonde apparatus and its corresponding value in relative humidity, as well as the sensitivity of the instrument to humidity, it is possible to determine the value of humidity according to the signals received.

Figure 166 schematically shows the general view of the instrument. On a metallic body and rigid frame, recorders of the following are mounted: pressure (1), temperature (2) and humidity (3), whose indicators slide along the pressure (4), temperature (5) and humidity (6) combs. The propeller (7) brings the main commutator (8) and the humidity commutator into rotation; the sliding contact of the latter slides over the humidity disk (9). On the wall of the body a radio transmitter (10) is mounted. The instrument is placed in a cardboard casing having a ventilation shaft on one side. In this shaft, the recorders of temperature, pressure and humidity are located, whereupon, for better insulation, the shaft has a double wall with an intervening air space. On top of the casing the power supply batteries (11) are located. Four cords with a ring are attached to the upper portion of the casing in order to suspend the instrument from a balloon.

Figure 167. Diagram of the radio transmitter.

Figure 168. Assembly diagram of the radio transmitter.

The radio transmitter is a self-controlled Gartley (Hartley) assembled around a UB-107 or UB-152 (Figure 167) tube. The transmitter is mounted on a tube panel (Figure 168). One end of the self-induction coil L is connected with the socket of the screen S and the movable plate of the variable condenser $C_1$ , the other end with the stationary plate of the same condenser $C_1$ and with the plate of the fixed condenser $C_2$. One end of the choke coil $L_a$ is left free for contact with the positive terminal of the anode battery, the other end is connected to the anode socket of tube A and with the second plate of the fixed condenser $C_2$. A conductor d is connected to the negative terminal of the filament battery.

Two conductors are connected to the socket of +H: one of them ends as a contact b to connect with one of the bare coils of the self-induction coil, and the other lead g ends as a fork for connection to the frame of the instrument. In order to connect the self-induction coil with the antenna there is a lead from contact a.

As a power supply, batteries of the Leklanshe type elements are used: two anode batteries of 45 volts of four of 22.5 volts, connected in series and a 6 volt filament battery. The life of the batteries is calculated for about 2 hours of continuous operation.

The transmitter of the radio sounding apparatus operates in the 19-34 meter band. The antenna, 7 meters long, is attached to the balloon filled with hydrogen. A counterbalance is attached to the frame of the instrument with the aid of a piece of wire.

The flying weight of the instrument with complete equipment is about 1,000 grams.

## No 4. THE COMB RADIOSONDE APPARATUS PZ-049

The radio sounding apparatus PZ-049 works on the same principles as the apparatus described above. Its main difference is in the different construction of the pressure unit. As a pressure recorder, two bi-metallic aneroid boxes, kinematically attached to the thermocompensator (Figure 169), are used. Therefore, the need to introduce corrections to the pressure readings of the pressure recorder influencing the temperature is eliminated.

Figure 169. A general view of the radiosonde apparatus PZ-049.

The action of the compensator is based on the fact that the movement of the membrane system of the pressure capsules is transferred to a special elbow through a bimetallic plate, which, as is evident from Figure 169, is attached to the pressure recorder. During a change in temperature of the pressure capsule and the bimetallic plate, the transfer relation changes in the kinematic chain from the pressure capsule to the indicator, which slides along the pressure comb. Thus, for example, with a lowering of temperature of the pressure capsule its sensitivity is lowered, but thanks to the curve of the bimetallic plate, the point of its contact with the elbow, and the transfer relation in the kinematic scheme is increased, so that it increases so uniformly that the sensitivity of the pressure unit as a whole is maintained constant and independent from the temperature. The elbow of the thermo-compensator is always held to the bimetallic plate by a special spring which is attached to the axis of the indicator of the pressure recorder.

So that the pressure indicator will not slide along the contact comb under a constant pressure but due to changing temperatures the bimetallic plate and the elbow are coupled together at a definite angle. If, say, a lowering of temperature is observed, then the curvature of the membrane of the pressure capsules is decreased, and the bimetallic plate is moved together with the membrane of the capsule in a direction toward the indicator and at the same time toward the axis of rotation of the elbow of the thermocompensator. However, in this case the point of contact between the plate and the elbow slides along the rib of the elbow without turning it.

The next different characteristic of the radiosonde apparatus PZ-049 is the presence on the pressure indicator, in addition to a screw for the regulation of the pressure of the indicator on the contacts of the comb, of a special device for the setting of the initial position of the indicator. This makes it necessary to introduce corrections when going from the ordinate according to the instrument to the ordinate according to calibration (see No 12).

Because the pressure recorder is provided with a thermocompensator, it is taken out of the housing of the instrument, so that the ventilation of the temperature receiver and the humidity ~~receiver~~ recorder is improved during the flight of the radio sounding apparatus.

For better shielding of the temperature ~~receiver~~ recorder from the influence of radiation the housing is equipped with a special supplementary metallic shield.

In addition, the bad effects of play in all linkages of the instrument are eliminated by special spiral springs on the shafts of the indicators, and in order to diminish friction in their couplings, indicator shafts rotate on conical bearings.

## No 5. COMMUTATOR RADIOSONDE APPARATUS OF THE GGO SYSTEM

This instrument also belongs to the type of radiosonde apparatus using the number-impulse coding method. However, its coding device differs from the coding device of the radiosonde apparatus of the comb system, though the code of the signals is preserved.

Three rigid disks T, F P (Figure 170) with elastic commutator segments and two shafts CD and AB, rotated by a wind vane, is the coding device of the radio sounding apparatus of the GGO system. The rotation of shaft CD is transferred to axle AB by means of a tooth gear so that when the first makes 16 revolutions the second makes one revolution.

On shaft AB, opposite disk T, at an equal distance one from another, shaped contacts (star-wheels) a, b, c and d are located. These serve for the coding of temperature values. Opposite disk F, star-wheels a', b', c' and d' are located. These are for the coding of humidity values. And opposite disk P, there is one star-wheel 1, for the coding of pressure. The distance between temperature star-wheels, as well as humidity star-wheels, is equal to the width of the commutator segments, i.e., 1.5 millimeters. Star-wheels a, b, c, d have narrow contact points numbering from one to four, while star-wheels a', b', c' and d' give a combination of narrow and broad contacts: star-wheel d' has one broad contact, c', one broad and one narrow contact, b', one broad and two narrow, and, finally, star-wheel a', one broad and two narrow and one even broader contact. Star-wheel 1 has two contacts of which the second is by 1 millimeter shorter than the first.

Figure 170. Diagram of the commutator radiosonde apparatus of the GGO system.

The temperature recorder is a bimetallic spiral T'. During a change in the temperature, the bimetallic spiral brings into rotation the axle with the disk T attached thereupon. The commutator segments of disk T lie in its plane, and, during a change in temperature, thanks to the rotation of the shaft with the star-wheels, they will touch the latter. In this, contact of the commutator segments with the star-wheels during a lowering of temperature is made in the following order: first with star-wheel d, then with star-wheels c, b and a, i.e., signals in the form of one dot, two dots, three and finally four dots are received. Further, in the same order, contact with star-wheels of the next and following commutator segments is made.

In a reverse movement of the temperature, the succession of signals is inverted, because the disk in this case rotates in an opposite direction. The temperature signals are brought into sections of 4 signals in each. In accordance with the number of commutator segments, the whole temperature range change is covered by 24 sections.

For the determination of the numerical order of the section a system of ten control signals is introduced. The ten contacts of star-wheel N, lying in a plane parallel to disk T, serves this purpose. These points make contact with lever f, touching the control star-wheel e with seven contact points. Therefore, when one of the points of the control star-wheel approaches lever f, we will hear seven short signals in the form of dots. The succession of control signals remain the same as in the comb radio sounding apparatus of Molchanov's system.

The humidity recorder, in the form of a taut strand of hair R, rotates the humidity disk F having 4 laminas by means of an elastic shaft. The laminas of the humidity disk make contact with star wheels a', b', c' and d', so that the location of the humidity star-wheels on the shaft AB determines the transmission of humidity signals in the interval between the separate series of temperature and pressure signals. In accordance with the structure of the star-wheels, the humidity signals always begin with a long dash. No control signals for humidity are provided.

A system of two springless aneroid boxes B' serves as the pressure recorder, which in a change of pressure brings disk P into rotation by means of a lever and a gear transmission P'. That lamina of the disk P determines the lengthening of the last temperature signal which comes into contact with the longer point of star-wheel 1, as is the case in the comb system. The eleventh, fifteenth and nineteenth laminas of disk P are longer than all of the rest by 1 millimeter. Therefore, only these laminas will make contact with the shorter point of star-wheel 1 giving the control pressure signal, covering all humidity signals.

The transmitter of the radiosonde apparatus is designed along a modified three-point system and mounted together with the radiator and the power supply in the form of a separate radio chassis. When placing the radio chassis into the radiosonde apparatus, there is an automatic insertion of the instrument into the circuit of the transmitter without additional connections. A switch contact is provided for the power supply.

One lead-zinc element, or an acid battery, included in a primary coil of a vibrator transformer G, is used as the power supply. The current to the tube filament comes directly from the power supply. Feeding of the anode is done from the secondary coil of the vibrator transformer, giving an alternating current of 150-200 volts. In this manner, transmission is effected by tone modulated signals which increases the reliability of signal reception. The reception of signals is by sound.

The above described system has a series of advantages over other systems of the number-impulse method of coding, particularly in comparison with the comb system. A sufficient rigidity in construction ensure the non-variation of calibration data. The lack of an assembly system of conductors results in simplicity of construction and rapidity in preparing the instrument for operation. Unlike the comb radiosonde apparatus, where the indicators of the ~~receivers~~ recorders move along the comb with friction, in this system the contact of the lamina of the disk with the star-wheels of the commutator is made in a direction perpendicular to the rotation of the disks and not parallel. Finally, with this instrument measurements are transmitted with greater frequency (every 5-10 seconds) than with the radiosonde apparatus of the comb system.

As to disadvantages of the radio section, the not fully reliable operation of the vibrator transformer (as a result of the clogging and burning of its working contacts), the non-uniformity of frequency of the sound oscillations and presence of a wide frequency band during transmission resulting in broad tuning of the receiver, should be mentioned.

The flying weight of the instrument is about 600 grams, which is much less than many other existing designs.

Figure 171. Diagram of connections of the recorders with disks of the condensers in the "Volna" radiosonde.

## No 6. "VOLNA" (WAVE) RADIOSONDE APPARATUS

The "Volna" radiosonde apparatus belongs to the group with a frequency method of coding. The variable parameter of the oscillating circuit in this system is the capacity load, the variation of which is directed by the meteorological recorder according to the active surface of the condenser plates. The temperature recorder



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bimetallic plate T (Figure 171), is connected through its free end, with the aid of T-shaped lead and a gear rod, to the variable condenser disk $C_t$. A driving gear is fastened to the shaft of the disk, and the end of the gear rod is connected to the driving gear. The disk of the condenser has an opening in the shape of a sector with an angle of 135 degrees. On its edge it has a scale for the measurement, with the aid of an index, of the angle of rotation of the disk. During a drop in temperature, the movement of the free end of the bimetallic plate, through the gear rod and driving gear, results in a rotation of the disk in a direction of increase in the divisions of the scale, counter-clockwise. With an increase in temperature the disk rotates in the opposite direction.

A strand of hair F serves as the humidity recorder, one end of which is fastened, and the second, wound around the shaft of the condenser, goes through an opening in it and is connected to a spring. At a change of the humidity, the lengthening or shortening of the strand of hair results in a rotation of the disk of the variable condenser $C_f$.

With the aid of a mechanism similar to the one described for the recorder of temperature, a system of two aneroid boxes B, due to their deformation with a change of pressure, results in the rotation of the variable condenser $C_b$. The disks of the variable condensers have contact with the frame and are connected to the end of the anode coil of the transmitter.

Besides the mentioned disks of the variable condensers, there are two fixed capacity disks, one of which $C_M$ determines the maximum capacitive load in accordance with that given by the variable condensers, the other $C_m$ determines the minimum. Each



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of these disks also has an opening in the form of a sector having an angular size of 135 degrees. The disk of the maximum load is determined by the position of the solid portion within the mechanism, and the minimum load disk -- with the opening within the mechanism.

For the switching into the transmitter of the variable load disks, whose position depends on the state of the meteorological elements, as well as the maximum and minimum load disks, there is a central load switch P. It consists of two condenser plates in the form of a sector and a mechanism operated by successive switching into the chain of the oscillating circuit of disks of variable and fixed capacitive loads. The condenser plates of the central switch cover the disks from both sides so that successively, only one disk can be covered exactly. Then the capacitive load of the oscillating circuit will be determined by the area of the disk between the two other plates of the condenser.

The mechanism of the central switch is brought into operation by the propeller with a vertical axis of rotation. As a result of the action of the air flow during the ascent of the radiosonde apparatus, the propeller rotates and with the aid of a worm gear forces the central switch to rotate. A special device in the form of a reductor with a five-pointed Maltese cross then determines a successive movement of the central sector plate in such a way that each position is maintained for a period of several seconds. The central sector is insulated from the frame of the instrument and is connected to the start of the anode coil. In this manner the successive contactless inclusion of all capacitive loads in the transmitter is provided for.

The distribution of recorders and condenser plates in the instrument is such that the capacitive load switch successively includes the disk plate of the condenser connected to the temperature receiver, then the minimum load disk, the humidity disk, pressure and finally the maximum load disk. In this manner, the frequency of the emitted oscillations will successively depend on the value of the temperature, humidity and pressure of the air. Thus the frequency values (or the wavelengths), characterizing the value of the measured meteorological element, are taken within the relatively extreme values of the radiosonde apparatus corresponding to the maximum and minimum capacitive loads. By this the influence of normal factors on frequency changes are taken into account.

Furthermore, the measurement of meteorological elements is made cyclically, so that the cycle of switching is completed in 15-20 seconds, and each of the disks connected to a recorder, as well as the disks of constant capacitive loads, are switched in for a period of 3-4 seconds, which is fully sufficient for fine tuning when receiving signals.

Figure 172. Basic scheme of the radio transmitter and the system of inclusion of capacitive loads. C -- trimmer; $C_1$ -- antenna connection

condenser; $L_1$ -- anode circuit coil; $L_2$ -- reverse contact coil; 1 -- maximum capacitive load condenser; 2 -- temperature condenser; 3 -- minimum capacitive load condenser; 4 -- humidity condenser; 5 -- pressure condenser.

Figure 172 shows the basic scheme of the radio transmitter.

The radio transmitter is built around a miniature UB-240 tube using series feed with inductive coupling of the screen. Parallel to the capacitive load of the condenser of the oscillating circuit C, the capacitive loads of the receivers 2, 4, 5 and the constant loads 1, 3 are included. The working frequency band of the transmitter, corresponding to the maximum and minimum capacitive loads, ranges from 23.5 to 25.3 megacycles. The transmitter is powered by wet cell batteries with lead-zinc elements of 2.2 and 80 volts. The mounting of the transmitter is done with due regard for the greatest operating stability and ease of preparation of the radio set for ascent with the radiosonde.

Figure 173 shows the exterior view of the instrument. In its front part, the recorders, the disk condensers, the capacitive load switch and the switching mechanism are situated; in the upper part, the transmitter, and in the lower, the battery power supply. The instrument is placed in a casing with a metallic cover. The recorders of temperature 1 and pressure 2 are shielded from the effects of radiation by metallic housings. The humidity recorder 3 is situated inside a trough-shaped cantilever bracket with openings which is a shield for the recorder. The cover of the instrument serves as a shield from atmospheric effects for the mechanism of the radiosonde apparatus. Opposite the disk indexes are celluloid windows which permit the measurement of disk positions without removing the cover. Through the bottom of the instrument, emerging downward, is the end of the shaft on which the propeller is mounted.

The radiosonde apparatus is attached to balloon of type No 100, filled with hydrogen up to a free lifting force of 1,200 kilograms.

For a smooth descent of the instrument after bursting of the balloon a parachute situated between the balloon and the instrument is provided.

The setting of the instrument consists in the determination of the position of the disks and, therefore, the frequency of transmission of the various values of meteorological elements.

Figure 173. A general view of the "Volna" radio sounding apparatus.

In order to receive signals from the "Volna" radiosonde apparatus, registration of two types may be employed: (1) semi-automatic and (2) automatic.

The semi-automatic registration consists of the radio receiver and a registering device. The receiver is built on the superheterodyne principle with a tuning device concentrated in one dial. In order to raise the tuning accuracy, a hand wheel of comparatively large dimension is attached to the tuning condenser shaft.

The hand wheel of the receiver, with the aid of a stringed connection, is tied in with a carriage moving synchronously with the tuning of the receiver along the surface of a drum (along its generatrix). The drum is rotated by a clock mechanism. A tape is fastened to it, on which the recording of signals is effected.

In this manner, upon the rotation of the tuning hand wheel of the receiver, the carriage will move so that a definite position of the hand wheel results in a definite position of the carriage, i.e. the ordinate of the registration. The carriage is provided with a needle which punctures the tape on the drum. At the moment of tuning, the operator presses a lever which frees a bow striking the needle of the carriage, and the point on the tape will denote the ordinate corresponding to the position of the hand wheel, i.e., the frequency emitted by the transmitter of the radiosonde at the moment of measurement.

In practice, precise tuning is determined by the discovery of the signal heard on the telephone or the reproducer. As was stated, such tuning and recording of the signal must be done in cycles every 15 to 20 seconds, successively tuning in 3-4 seconds on the frequency determined by the indicators of the temperatures humidity and pressure recorders and the maximum and minimum capacity loads. In this manner, as a result of the reception of signals, we obtain a record of the path of meteorological elements as a function of time.

Calculations on data obtained during the operation of the comparatively large dimension is attached to the tuning condenser shaft.

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Calculations on data obtained during the operation of the instrument and setting graphs allow the registration to be processed similarly to the processing of meteorograms or signals of radiosonde apparatus of the comb system. It is necessary to remember, that the ordinates of the registrations are always taken relative to the distance between the line of registration for the maximum and minimum capacitive loads, by means of which the corrections for frequency distortions in the transmission due to various factors are introduced.

## No 7. RADIOSONDE APPARATUS OF THE LANG SYSTEM (GERMANY)

The radiosonde apparatus of this system may be included in the group of the time-impulse method of coding.

The movable end of the bimetallic temperature recorder, with the aid of a toothed rack and pinion brings into contact the contact star 1 (Figure 174), the points of which slide along shaft 2, made of ceramic insulating material. On the shaft two contact spirals are located. Clock mechanism 3 brings the shaft into rotation with a velocity of 1 revolution per minute, so that one of the points of the star makes 2 contacts on the spirals during this interval. On the narrower portion of the shaft, a contact plate for the initial time signal is located; the signal is given by pen 4 times a minute. The intervals of time between the initial signal and the signals received upon the contact of the points of the star, controlled by the temperature recorder, with the spiral on the rotating shaft, give the position of the point on the shaft and, therefore, the corresponding value of the temperature.

The angular distance of the points of the star are so selected



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that in the rotation of the star one of the points will leave the shaft when the next point is already on it. The range of signals given by one point correspond to an interval of temperature of about 15 degrees.

For the measurement of humidity, a hair hygrometer 5 may serve, whose change in length, with the aid of a lever, results in a change of the movable contact (pen), giving a signal following the initial time signal without changing the instant of the start of this signal. In this manner, the measurement of humidity, in contradistinction to the measurement of temperature, is done once during a revolution of the shaft, i.e., once per minute.

The measurement of pressure is done by the aneroid box 6, which with the aid of a lever transmission controls a contact pen sliding along a plate of insulating material 7. On the plate, at definite distances from one another, contact strips are located in such a manner that a movement of the pressure pen from one contact to another will correspond to a change in altitude of about 1,500 meters. The contact of pressure pen with the said strips on the plate results in a change in the capacitive load of the oscillatory circuit, which in turn results in a sharp change in frequency. Analogous effects upon the frequency of transmission are the results of contacts of the points of the temperature star, the humidity pen and the pen for initial time signals.

Each time when there is a closing of the circuit through one of the indicated contacts, there will be a shorter or longer pause in the sound heard in the receiver tuned to the transmitter of the radiosonde apparatus, which pause will serve as either the initial or the working signal for each of the meteorological elements.

The transmitter of the radiosonde apparatus is designed along a three-point scheme and works on a 90 meter wavelength. Either wet or dry cell batteries of 45 and 2 volts are used as the power supply. Automatic registration is used in the reception of signals.

No 8. THE RADIO RADIOSONDE APPARATUS SShA (USA)

In this sytem of radiosonde apparatus, the recorders of temperature and humidity play the role of variable parameters of the oscillating circuit, namely: upon changes in temperature and humidity, the resistance of the recorders changes, which results in a change in the period of the low-frequency oscillations of the relaxed-type modulator. The period of oscillation of such a generator may be expressed approximately with the aid of the formula $T = RC$, where R is the resistance and C the capacitive load.

Figure 175. Diagram of the radiosonde apparatus SShA.

Serving as the pressure recorder of the radiosonde is a system of two aneroid capsules 1 (Figure 175) whose deformation due to a change of pressure results in a transfer of the contact pen along the commutator 2, which is an assembly of conducting and insulating plates. The position of the contact pen on the commutator serves as the measure of pressure. Besides, the pressure recorder fulfills the role of a switch with the aid of a pen alternatingly switching into the transmitter the recorders of temperature and humidity as well as the control resistance.

Serving as a temperature recorder is a semi-conductor -- a thermistor 3, of cylindrical form, possessing a great negative temperature coefficient of resistance, i. e., upon a lowering of temperature, the resistance of such a recorder will increase and vice-versa.

The measurement of humidity is based on the utilization of the characteristic of a hygroscopic film which makes it change its electro-conductivity with a change of humidity. The humidity recorder 4, built on this method, is a glass plate coated with a film of hygroscopic LiCl Salt solution. The film plate is bordered by conducting strips on two sides for its inclusion into the circuit of the radiosonde apparatus. When processing the data from such a recorder, temperature is taken into account.

The recorders of temperature and humidity are mounted in a cylindrical housing, protecting them from the direct influence of solar radiation yet allowing the free ventilation by air flow.

The pressure recorder includes in its circuit the temperature and humidity recorders with the aid of special relay 5.

The frequency of the relaxed oscillations of the modulator depends on the resistance of the measuring portion of the radiosonde apparatus, included in the screen circuit of the modulator 6. The anode circuit of the modulator has a capacitive load coupling with the screen circuit of the generator of the carrier frequency 7, so that the latter is modulated by the method of low-frequency modulation of the carrier frequency.

The work of the instrument is done in the following manner. In the ascent of the radiosonde apparatus, the pressure contact pen moves along commutator 2. When it is located on an insulating plate of the commutator, then the temperature recorder is included in the circuit; when it moves to a conducting (metallic) plate, then the relay is activated switching out the temperature recorder and switching in the humidity recorder. Besides these humidity contacts, the commutator has control resistance contacts 8.

The reception of signals is done by a receiver equipped with a registration device.

As we have seen above, the transmitter of the radio sounding apparatus represents two [frequency] generators. The generators work on two halves of one tube. Together with all the parts of both generators the transmitter is mounted between two texolite plates. The right generator (Figure 175) of the carrier frequency works on a UKV on a band of 72.2 megacycles (about 4.2 meters); the left generator, of the relaxed type, modulates the oscillations of the right one with an amplitude within 10 to 200 cycles. The power supply batteries represent a unit of dry elements, composed of two sections: one of 3 volts -- for the tube filament, the other of 90 volts -- for the tube anodes.

The weight of the instrument without batteries is about 700 grams and with the complete equipment -- about 1,300 grams.

## No 9. PECULIARITIES IN CHECKING COMB RADIOSONDE APPARATUS

In order to determine the values of meteorological elements according to the signals of the radiosonde apparatus at corresponding moments of time, it is imperative to know their values for the positions of the indicators on the combs prior to the ascent of the radiosonde and the sensitivity of the recorders of the instrument. Sensitivity of the recorder is the change in temperature corresponding to the movement of the indicator through one tooth of the temperature comb. The sensitivity of the pressure and humidity receivers is determined by the changes of pressure and humidity corresponding to the movement of the indicator through 1 millimeter of the comb.

Calibration of the radiosonde apparatus has the aim of determining the sensitivity of the ~~receivers~~ recorders and in principle does not differ from the checking of meteorographs described in Chapter III.

Before testing a technical inspection of the instrument is conducted aiming at the disclosure and elimination of mechanical defects. Attention is directed to seeing that the temperature and pressure receivers are not bent or sagging, and that the bimetallic plate of the temperature ~~receiver~~ recorder has no cleavages. The shafts connecting the levers of the ~~receivers~~ recorders with the indicators must not have a large play. The ends of the indicators must travel parallel to the combs with the same amount of pressure. The strength of the frame supporting the combs, commutator and other parts, the reliability of the coupling of the commutator axle with the bearing of the humidity switch, the absence of friction in the shaft of the indicators and lever transmission, the correctness of the position of the star-wheels on the shaft of the commutator and equality in the pressure of all laminas upon the points of the matching star-wheels, -- all these are checked. Besides, several other aspects of the operation of the mechanism of the instrument are checked.

Further, regulation of the sensitivity of the pressure and humidity recorders is made. For pressure it is necessary to set the sensitivity to 13-16 milligrams for 1 millimeter of the ordinate of the comb, and for temperature, 1.3 to 1.58 [degrees] for one tooth.

Before regulation, the initial position of the pressure indicator C (Figure 176) on the comb is determined. In order to change the position of the pen, holes H in lever T are utilized, connecting lever B running from receiver to sensitivity angle A. Changing the position of pin P along the various openings of the lever, the indicator is set along various parts of the comb depending on the pressure.

Figure 176. Fastening of the shaft on the sensitivity angle.

For the determination of sensitivity the radio sounding apparatus is placed in a pressure chamber where the air is rarified to 70 millibars. Knowing the position of the indicators before and after rarification, the sensitivity is determined. In case it is necessary to change the sensitivity, screw K connecting the lever is moved closer or farther to the axis of the angle O, because through this the ratio of the levers of the transmission mechanism is changed, and, consequently, the distance of travel of the indicator.

The regulation of the temperature recorder is made analogically. For the determination of sensitivity the temperature recorder is immersed in a cooling mixture. Knowing the temperature and the position of the indicator on the comb before and after immersion of the recorder in the cooling mixture, the sensitivity is determined with the aid of the relation

$$\Delta t = \frac{T_1 - T_2}{n}$$

where $T_1$ is the reading of the control thermometer at a positive temperature, and $T_2$, the reading of the control thermometer at a negative temperature, n is the number of teeth in the comb traversed by the indicator upon the change of temperature from $T_1$ to $T_2$.

By the resetting of the screw connecting the lever to the angle, the sensitivity is regulated to the necessary amount.

The checking of the humidity recorder is usually done in a pressure chamber. The checking is done only in the direction of lowering the pressure according to the following steps: at an atmospheric pressure of 850, 700, 550, 400, 250, 150, 100 and 70 millibars. When reaching the stated pressure values, an accurate manometric measurement of the position of the indicator on the pressure comb, with an accuracy up to 0.1 of each tooth, is made. The results of the check are plotted on a graph. Along the horizontal axis, the teeth of the pressure comb, on a scale of 1 millimeter of the comb equal to 3 millimeters of the graph, are plotted, and dashes are used to plot the position of the teeth, and numerals denote the number of the metallic tooth. Along the vertical axis, the pressure on a scale of 1 millibar = 0.5 millimeter is plotted. A curve is drawn along the points corresponding to the position of the pressure indicator and to the measurement of pressure by the manometer; the curve will serve as a certification or a graphical check on the pressure (Figure 177, a).

Figure 177. Calibration graphs of the comb system radio sounding apparatus.

In order to consider the effect of temperature on the indicator of the pressure recorder, the latter is checked at a negative temperature of -60-to - 45 degrees. For this, the radiosonde apparatus, with the pressure recorder immersed in a cooling mixture, is placed in a pressure chamber and checked under atmospheric conditions of 800, 600, 400, 200 and 70 millibars. The pressure check curve at a negative temperature is drawn on the graph used for positive temperature, as is shown on Figure 177, a.

Calibration of the temperature recorder is made in a double-walled metallic tank into which alcohol is poured, cooled with solid or liquid carbonic acid. Changes in temperature are made in an upward direction through steps of 20 degrees up to 30 degrees. When the temperature indicator of the recorder immersed in alcohol settles, its position is measured on the comb, indicating the section, the number of the tooth and its position on the tooth in tenths of the tooth distance from the beginning of the tooth. At the same time, the temperature is taken with the control thermometer.

The calibration graph is plotted in the following manner. Along the horizontal axis, the teeth of the temperature comb, on a scale of 1 tooth = 5 milligrams of the graph, are drawn; numerals indicate the section number. Along the vertical axis, in degrees, on a scale of 1 degree = 5 millimeters of the graph, the temperature is plotted. Along the points of indicator position measurement and the respective values of temperature, a line is drawn, which will be either straight or with two or three breaks (Figure 177, b). In the latter case the value of the sensitivity is determined for each portion of the broken line separately.

The humidity recorder is checked in a hygrostat. The checking is begun with a relative humidity near 100 percent, after which the humidity is lowered according to steps: 80, 60, 40 and 30 percent.

At a humidity near 100 percent, the humidity indicator must be at the start of the second tooth of the comb. In an adverse case, it is necessary to adjust the pen. Changing the humidity in the hygrostat according to the steps mentioned, measurements of the humidity indicator and of dry and wet thermometers of the psychrometer are made. On the calibration graph (Figure 177, v) along the horizontal axis, the teeth of the comb, on a scale of 1 millimeter of the comb = 1 millimeter of the graph are plotted. The numerals 1, 2... denote the number of the tooth. Along the vertical axis, the values of relative humidity on a scale of 1 percent = 1 millimeter of the graph are drawn.

## No. 10. PREPARATION AND ASSEMBLY OF THE COMB RADIOSONDE APPARATUS PRIOR TO FLIGHT

### CONTROL CHECK OF SENSITIVITY OF ~~RECEIVERS~~ RECORDERS

Prior to release for flight, each radiosonde apparatus must be submitted to a control check. The control check aims at establishing the allowable tolerance accepted during calibration, as well as the absence of changes of sensitivity of the recorders over and above the accepted limits in comparison with the graph data.

The observance of tolerances is determined according to the data of the calibration graphs. It is necessary that the temperature adjustment of the pressure recorder be no higher than 0.40 millibar degree, and the difference between the successive coefficients of sensitivity of the temperature recorder $\Delta t$ be not higher than 0.20 degree. Further, the positions of the pressure and humidity indicators are compared at the given condition with that which took place during calibration. Thus, for example, the ordinate of the position of the pressure indicator found according to the table of ordinates of the teeth of the pressure comb should not differ from the ordinate found for the same pressure on the calibration graph, by more than 15 millimeters.

The control check of the sensitivity of the pressure recorder is usually made in a Garf (see Chapter III) chamber. It is conducted in the same manner as the basic check, but is made along broader steps of pressure change. The comparison of ordinates obtained for one and the same pressure on the data of the control check and the calibration graph, makes it possible to determine the suitability of the instrument for flight. The radiosonde apparatus is considered suitable for flight if the maximum and minimum difference of the ordinates does not exceed 2 millimeters. An orderly increase of differences will show a change in sensitivity; in this case the curve of the control check will have a bend toward the axis along which the pressure is marked, differing from the angle of bending of the curve of the basic calibration.

The control check of sensitivity of the temperature and humidity recorders is made by way of comparing the changes in values of temperature and humidity by an aspiration psychrometer and a radiosonde apparatus. For this, the measurements on the psychrometer and the position of the indicator are made under room temperature conditions and in the open air. According to the positions of the indicators in the room and in the open air, and knowing the values of the temperature and humidity according to the measurements of the psychrometer in the room and using the sensitivity given by the check the temperature and humidity in the open air is determined. The divergence of the temperature found according to the instrument with the psychrometer values must not be higher than half of the sensitivity obtained in the check. The tolerance of divergence for humidity should be 8 percent.

## PREPARATION AND ASSEMBLY OF THE RADIOSONDE APPARATUS FOR FLIGHT

The preparation of the radiosonde apparatus for flight is summarized by the following operations:

(1) check and tuning of the transmitter;

(2) technical inspection and regulation of parts of mechanisms of the instrument;

(3) check of electrical connections;

(4) check of battery water;

(5) assembly of the instrument.

In the check of the transmitter, first of all the suitability of the oscillator tube is tested by placing it in the detector tube socket of the receiver. Then, having attached clips of the induction coil to the transmitter, the power supply is turned on, and on the antenna, a wattmeter of a milliammeter is connected in series. A sharp deviation of the instrument indicator will show that the transmitter is working. In order to obtain the maximum output in the antenna, a transfer of the clips on the self-induction coil and regulation of the variable condenser is made. Finally, in order to avoid the effects of interference with signal audibility, the tuning of the transmitter is so regulated with the aid of a receiver that within the bank of wave oscillations of the transmitter no other radio stations are operating.

The technical inspection of the radiosonde apparatus is conducted analogically to that which is made prior to the calibration of the instrument. Special attention must be paid to the ease of rotation of the propeller and commutator shafts, the correctness of pressure of the laminas on the commutator star-wheels, and the indicators on the combs, as well as the parallel movement of the indicators over the combs.

The pressure of the indicators is regulated by screws. Defects found are eliminated by corresponding regulating. For positive connections, all contacts are cleaned with a fine file.

The check for correctness in the electric circuit is made with the aid of a sound generator, a buzzer or electric light bulb. One lead from the sound generator is connected to the frame of the instrument, and the other, to the commutator; then the power supply is turned on. Placing the temperature indicator successively on the 1, 2, 3, 4 and control tooth, and rotating the axle of the propeller, the signals are heard. If the circuit is correct, the signals will correspond to the teeth numbers. In the same manner humidity and the control tooth of the pressure comb are checked. The defects found are usually due to the closing of the circuit leading to the lamina or the plates on the humidity disk as well as closing of the combs.

Batteries are filled with an electrolyte which is composed of a saturated solution of ammonium chloride. Filling is done with the aid of a rubber bulb fitted with a pipette. The anode battery is connected in series. In case a UB-152 tube is used a change in the connections of the elements of the battery designed for 6 volts is made to series-parallel. The EDS of such a battery will be equal to 3 volts.

Assembly of the instrument consists of the following. On the frame of the instrument the transmitter is attached, and in the lower portion of the frame a lead is fastened to which a counter-balance connected to the instrument body is attached. The instrument is placed in a casing having an additional shield against radiation for the temperature recorder. The batteries are placed on top of the casing. The leads from the batteries are connected with a four-prong plug which is located on the side of the casing shaft.

When the assembly is finished a check of the transmitter operating on its own batteries is made.

## No 11. PRODUCTION, TRANSMISSION AND RECEPTION OF SIGNALS OF THE RADIOSONDE APPARATUS

Because the signals of the radiosonde apparatus do not transmit absolute values for meteorological elements but their changes, it is imperative prior to the release of the radiosonde apparatus, as it is for airplane meteorographs, to compare the position of their indicators with the data from absolute instruments: the mercury barometer and aspiration psychrometer. For this, it is necessary to maintain the radiosonde apparatus for a sufficient length of time in identical conditions with absolute instruments.

The readings of the instruments will be comparable only when the recorders of the radio sounding apparatus will be affected by the pressure, temperature and humidity corresponding to the conditions of the time interval.

This exposure is one of the more important phases of preparing the instrument for flight, on whose accuracy of performance depends the accuracy of sounding. For control the exposure is made indoors and outdoors.

The radiosonde apparatus is placed in a ventilating device which draws air through the housing of the instrument with a velocity of 4-5 meters per second. Adjacent, an aspiration psychrometer is suspended. The batiste is wetted and the aspirator is turned on simultaneously with the ventilator. After 5 minutes a reading on the barometer and the psychrometer is made and the position of the indicators on the combs, with an accuracy of 0.1 of a tooth, is measured.

The main exposure is outdoors. The data obtained this way are those used for the processing of signals. For this, within 20 to 30 minutes prior to its release, the instrument is taken outdoors and suspended from a pole having a shield against the sun. Then the antenna is attached to the instrument and connected to the lead from the coil of the transmitter and, having turned on the power supply, the propeller is turned. The observer at the receiver turnes in on the wavelengths of the transmitter and checks the reliability of signal transmission comparing them to the position of the indicators. The readings of the indicator positions and the readings according to the aspiration psychrometer are made after the instrument has been ventilated for not less than 10 minutes. The ventilation of the recorders of the radiosonde apparatus is done either in a ventilating device or in a ventilating booth, but always shielded from solar radiation.

Using the data of the exposure indoors and outdoors the quality of the exposure is checked in a similar fashion as data from a control check. If the quality of the exposure corresponds to the tolerance accepted the data of the exposure are entered in the flight log. About 5 minutes before release, cloud, wind and other atmospheric observations are made. The results are entered in the log.

By this time balloon No 100 must be filled with hydrogen up to a lifting force of 2,200 grams, so that after attachment of the radiosonde apparatus ready for ascent, the free lifting force will be about 1,200 grams. This will assure the radiosonde apparatus of a 5-6 meter-per-second vertical velocity.

To the appendix of the balloon the second end of the antenna is attached, the power supply of the radio transmitter is turned on and the radiosonde is released.

For the determination of winds aloft, observations of the radiosonde balloon are made with the aid of theodolites (from one point or base points) and radio direction finders or radar observations are used.

Prior to the moment of release a complete series of signals of all elements is listened to and the results are entered in the log as data for the start of signal reception.

Then the reception of signals and their recording is conducted until the cessation of the signals.

The recording of signals is made by conventional symbols in the corresponding graphs of the log (see Appendix 4).

Temperature signals are recorded only upon their change; the time is noted with an accuracy of 0.01 of a minute is taken and the number of the new signal including the control signal is recorded.

At the time of reception, the section numbers of the temperature comb are also noted; the correctness of their rotation is verified by the control signals.

At the appearance of pressure signals, the time and the number of the temperature tooth is noted and in the pressure graph an X is recorded. At the moment of cessation of signals and analogous recording in the log is made, but in the pressure graph the symbol -- is placed. The appearance of the pressure control signal (three humidity call signals) is recorded in the form of XXX marks.

Humidity signals are recorded upon their displacement or upon their repetition -- after 1.5 to 2.5 minutes. In addition to the time and the number of the tooth of the humidity comb the number of the tooth of the temperature comb is noted and the corresponding pressure symbol is recorded if the pressure signal is being transmitted.

After the cessation of reception of signals, the cause for the cessation is recorded.

## No 12. PROCESSING OF RADIOSONDE SIGNALS

The processing of radiosonde apparatus signals is divided into several phases. First of all, the values of the meteorological elements are determined. Knowing the initial positions of the indicators on the combs and the values of meteorological elements during the exposure, as well as the sensitivity of the recorders (according to the calibration graphs), the values of the elements are found corresponding to the moments when the signals change.

Then, according to the values of pressure and temperature obtained, the altitudes are determined using hypsometric tables.

Further, according to the separate values of temperature and humidity corresponding to the moments of signal change, a graph of the changes of these elements as a function of time is plotted. In this same manner, using moments of time for which the pressure was determined, a graph of the changes of pressure according to altitude is drawn.

The four curves plotted make it possible to determine graphically certain points in the path of the temperature and humidity, and to determine for them the corresponding values of pressure and altitude. With the aid of the same graph, the values of meteorological elements for standard altitudes and main isobaric lines are determined.

An example of radiosonde apparatus signal processing is given in Appendix 4.

The processing of temperature signals is done in the following manner.

First of all, the temperature corresponding to the psychrometer reading at the moment of release of the radio sounding apparatus is recorded in the log. Then, knowing the position of the indicator and the value of the temperature during the exposure outdoors according to the coefficient of sensitivity, taken from the calibration graph, the temperature at the moment that the indicator touches the nearest tooth is determined. For this the change in temperature during the displacement of the indicator through one tooth (the coefficient of sensitivity) is multiplied by the number of tenths of the tooth, on to which the indicator had moved when moving to the next tooth. Using the coefficient of sensitivity and knowing, according to the succession of signals, the path of temperature change, the value of the temperature for all moments of indicator displacement from one tooth to another is calculated.

These data are recorded in the corresponding graph of the log. When processing signals for temperature inversion it should be remembered that the limit of transfer from one tooth to another, in any direction of transfer of the indicator, one and the same temperature will correspond.

It should be noted that in a weak inversion the absence of transfer of the indicator to another tooth in the opposite direction results in that this inversion is not revealed in the reception of signals.

When processing pressure signals it is first of all necessary to determine the correction for the change from the ordinate according to the instrument to the ordinate according to the calibration. The necessity for such a change is determined by the fact that the initial position of the indicator, determined during calibration, may change at the moment of release of the radiosonde apparatus, and for one and the same initial pressure the ordinates according to the instrument and according to the calibration will not coincide in value. Inasmuch as the pressure values can be determined by the signals of the radiosonde apparatus, using the calibration data, the ordinates according to the instrument should be brought over to the calibration ordinates. In this it can be assumed that the change of the initial position of the pen is not associated with a change in sensitivity. This condition should be supported by the control check.

The correction for the change from the ordinates according to the instrument to the ordinate according to the calibration is determined by the outdoor exposure data. For this, using the position of the pressure indicator at the moment of exposure, the ordinate according to the instrument is obtained with the aid of the table. The ordinate according to the calibration graph for pressure is determined, taking into consideration the temperature of the pressure recorder at the moment of exposure. Inasmuch as there are check curves for positive and negative temperatures on the calibration graph, the ordinate according to measurement calibration by barometer is obtained by interpolation between the two curves, using the magnitude of digression of temperature during exposure from that shown during calibration of positive temperatures. The algebraic difference between the ordinate according to calibration and the ordinate according to the instrument supplies the correction for the corresponding displacement. The correction for the displacement is considered constant and serves for the correction of all ordinates according to the instrument.

Then, according to the records in the log, the numbers of the metallic teeth of the pressure comb should be determined. The duration of the signals serves as a control for the determination of the number of the tooth. The ordinates for the centers of these teeth are then determined according to the table. In case of an unverified reception or absence of the start or the finish of the pressure signal, the ordinate for the start or the finish of the corresponding tooth is taken. The values of the ordinate obtained according to the instrument with the aid of the correction bring us to the ordinate according to calibration.

Utilizing the calibration graph, the value of temperature, taking into consideration the temperature of the pressure recorder with the aid of interpolation between the two verification curves, is found according to the ordinates obtained. The temperature corresponding to the passing movement of the indicator either through the center or through the start and/or finish of the tooth is accepted as the temperature of the recorder. Its value is determined according to the processing data of the temperature signals and is recorded in the "Temperature at Times of Pressure Measurements" column.

The values of pressure obtained are recorded in the corresponding columns of the log.

The processing of humidity signals is in the determination of the values of relative humidity for the moments of displacement of the humidity indicators from one tooth of the comb to the other. At first the correction which must be introduced into the value of the relative humidity, taken from the calibration graph, is determined. For this, according to the data of the exposure the values of the relative humidity corresponding to the measurements by the psychrometer are compared with the values obtained for the position of the indicator according to calibration.

The correction must serve to bring the values according to the calibration to the values of humidity computed by psychrometeric measurements for the times of signal changes.

The next phase in the processing of signals of the radiosonde apparatus is the computation of altitudes. For all values of pressure obtained by the psychrometric table the altitudes expressed in geo-potential meters are found and recorded in the "Altitude at 0 degrees" column. Then the thickness of the layers between altitu.es at 0 degrees is computed. The thickness of the layer is then corrected through the deviation of the mean temperature of the layer from 0 degrees. The mean temperature of the layer is found as an arithmetic average between the temperatures of the times of pressure measurements of the lower and upper limits of the layer. The magnitude of the correction is found by a nomogram shown in Chapter VII, depending on the thickness of the layer and the mean temperature. Absolute altitudes are computed by way of successive summations of corrected layer thicknesses. The initial altidue is taken as the altitude of the point of sounding above sea level.

Figure 178. Graph of the results of processing of signals from the radiosonde apparatus. 1 -- temperature; 2 -- humidity; 3 -- altitude; 4 -- pressure.

A graph is constructed according to the signal processing data and the determination of altitudes. Along the horizontal axis of millimeter paper, time on a scale of 5 millimeter = 1 minute is marked off; along the vertical axis -- temperature on a scale of 5 millimeter = 1 degree humidity; on a scale of 1 millimeter = 1 percent, and altitude on a scale of 1 millimeter = 20 geopotential meters, are marked off. In this manner, changes in temperature, humidity and altitude are given as a function of time. Besides that, on the same graph, the curve of the pressure change as a function of altitude is plotted. The pressure is marked off on the horizontal axis on a scale of 1 millimeter = 2 millibars.

A graph is shown on Figure 178.

If observations of the radiosonde are made by theodolites from base points, or if radar observations are made for the control of altitudes obtained from pressure signals, then from time to time the values of the altitudes obtained by the stated methods are plotted on the graph.

A graph with four curves permits the determination of the values of the pressure, temperature and humidity for standard altitudes and for special points on the temperature and humidity curves.

The determination of the value of temperature and humidity for standard altitudes is done in the following manner: on the altitude curve, a point corresponding to the given altitude is found, and moving along the vertical to the intersection with the temperature or humidity curves, the values of these elements are measured on the respective scales. For the determination of pressure, the pressure graph and the function of altitude are used.

For special points, the operation of finding the other elements consists of going along the vertical from the special point selected until the intersection of the curve of the other element and the altitude is found, and the corresponding values are measured. For the altitude obtained the pressure is found as was explained above.

For the main isobaric lines, first the altitudes are found, using the altitude curve, and then for each of the altitudes found the values of the temperature and relative humidity are determined.

If the pressure at the moment of release was less than 1,000 millibars, then the altitude of the 1,000 millibar isobaric line is found with the aid of tables and the temperature is computed along the temperature gradient in the first layer.

Further processing consists of the computation of supplementary characteristics, for example, specific humidity, dew points or other characteristics in accordance with the demands of the aerological code.

Having in mind the preparation of the results of radio soundings for publication, the vertical temperature gradients and the vertical velocity of the radiosonde apparatus are computed after the telegram has been sent.

## No 13. PECULIARITIES OF CALIBRATION OF THE "VOLNA" (WAVE) RADIOSONDE APPARATUS

As was stated above, the signals from the "Volna" radiosonde apparatus are registered on a tape. The registration represents three curved lines of the relative changes of meteorological elements situated between two control lines corresponding to the constant capacitive loads. Therefore, the aim of the calibration of this radiosonde apparatus is the establishment of a connection between the ordinates of registration and the values of each element. The ordinates are measured by a special transparent rule with reference to the distance between the zero line of the "minimum" and the "maximum" wavelength.

The rule represents a quadrilateral celluloid sheet on which 40 lines are drawn. In the upper section these 40 lines approach one another and form a band 160 millimeters wide and in the lower section, spread out over 240 millimeters, they grow further apart. The extreme right line is numbered "0", and the extreme left, "200". Such an arrangement of the rule permits the finding of the relative ordinate depending on the distance between the extreme outside control lines.

Inasmuch as the insertion of the disks connected with the recorders of meteorological elements and the disks of constant capacitive load into the anode circuit of the transmitter occurs upon the rotation of the capacitive load switch, then in the calibration it is necessary to bring the reductor connected with the switch into rotation. This is effected by the use of a small electric motor whose shaft is connected to the axle of the reductor. In addition a power supply battery is plugged into the transmitter.

When calibrating the pressure recorder, the radiosonde apparatus is installed in a pressure chamber (or in a Garf instrument). The electric motor is placed in this same chamber and the power supply is led through to the instrument. Then, as is customary, the pressure is lowered according to the accepted steps. The signals of the radiosonde apparatus operating in the chamber are received by the registering device, and at the moment of manometric measurement on the tape the corresponding pressure points and the points of minimum and maximum wavelengths are marked off. In order to take into consideration the effect of temperature on the reading of the pressure recorder, the latter is also checked at negative temperatures.

on the upper part of the graph Calibration graph of "Volna" radiosonde apparatus No 16 October 1948.

Figure 179. Calibration graph of "Volna" radiosonde apparatus.

The tape processing is done with the aid of a transparent rule. Placing the rule so that the zero line is on the point marked off as the minimum wavelength and the line on the rule marked "200" on the point marked off as the maximum wavelength, the value of the ordinate for the corresponding pressure is measured off.

The results of the calibration are plotted on a graph (Figure 179). On the graph, along its horizontal axis, the pressure is plotted on a scale of 1 millibar = 0.5 millimeter; along the vertical axis, the values of the ordinates from 0 to 200 on a scale of a unit of ordinates = 1 millimeter are plotted. The scale of ordinates is the general scale for all three meteorological elements.

The check curve P is drawn according to the pressure measurements and the values of the ordinates of the registration. This curve has its greatest ordinate under normal pressure; with a lowering of pressure to about 500 millibars, the ordinate diminishes; at a further lowering, the curve goes upward, i.e., the ordinate again increases. In this manner, the form of the curve resembles the letter V, having the point of reversal for a pressure of about 500 millibars.

Calibration of the temperature recorder is done analogically. Having placed the temperature recorder in a cooling mixture, points corresponding to the instants of measurement according to the control thermometer are marked off on the tape of the registering device while passing through definite steps of temperature (according to radiosonde signals).

Check curve T (Figure 179) is plotted according to the ordinates of points obtained with the aid of the transparent rule and according to the corresponding values of temperature. The temperature scale is placed along the horizontal axis on a scale of 1 millimeter = 0.2 degree. The temperature check curve is similar to the pressure check curve.

The humidity check is conducted in a hygrostat, as is customary. When plotting points on the graph, an irregular humidity scale is used. It is computed in accordance with the functional change in the length of the strand with a change in humidity. If the proper type of hair is used, the check points will fall along a straight line R.

## No 14. PREPARATION OF THE "VOLNA" RADIOSONDE APPARATUS FOR FLIGHT -- TRANSMISSION AND RECEPTION OF SIGNALS.

Before release, each radiosonde apparatus must undergo a control check. The pressure recorder is checked at room temperature through a range of atmospheric pressure from 50 millibars, by steps of 100 millibars each. If the new calibration curve is found near to the given curve on the calibration graph, or is shifted parallel to it on the horizontal, then the instrument is considered suitable for release and the subsequent processing of the tape must be done with a new calibration curve; in an adverse case the main check is done anew.

The control check of temperature is done either with the aid of a cooling mixture or along three points: in room temperature in a cooler place and in heated air. If the new data obtained do not give a divergence of more than 1 degree from the earlier calibration, or if the new check curve is displaced horizontally, but parallel to the earlier, then the instrument is considered fit for release. A correction is then introduced into the values of the temperature obtained from the processing during the main calibration. The correction corresponds to the difference between the values of temperature according to the new and the main checks.

The control humidity check is made at two values of humidity; first, corresponding to the humidity under usual room conditions, second, at a humidity close to saturation.

## PREPARATION OF THE INSTRUMENT FOR FLIGHT

If, according to the data of the control check, the radiosonde apparatus appears suitable for flight, then its preparation is continued analogically to that done prior to the release of the comb radiosonde apparatus. However, there are differences in the preparation, called forth by the peculiarities of the device and the signal reception of the "Volna" radiosonde.

The preparation is done in the following operations:

(1) technical inspection and regulation of the mechanical

assemblies of the radiosonde apparatus;

(2) the preparation and check of the operation of the registering device;

(3) filling of the battery.

In a technical inspection, special attention is given to the transmission mechanism from the recorder to the disk-condensers. It is necessary that the rack from the recorders should pass freely through the openings in the cover of the instrument. The connections of the rack with the driving gear attached to the condenser shaft must assure an even movement without too great a clearance.

The absence of sticking in the disk-condenser shafts is checked by testing for easy rotation of the disks and observing the return of the disk indicator to the previous position. The freedom of rotation of the reductor shaft and the coupling in all gears is tried out.

Defects found are deleted on the spot.

The registering device is then included and its installation and readiness for reception is checked.

A paper tape is attached to the registration drum and the clock mechanism is wound. The attachment of the carriage is regulated in such a manner that for the minimum wavelength, at a frequency of 25.3 megacycles, the carriage is found in the extreme right position. The operation of the striking bow and the return of the needle is checked.

For a check of radio interference, interference points on the tuner are marked with crosses on the tape.

A test run in a room is then made. The ordinates of the registration on the tape according to the instrument are compared with the ordinates according to calibration for values of the meteorological elements obtained by psychrometric and barometric readings. Small divergencies will become additional corrections in the event of their confirmation during outdoor testing.

The batteries are then filled with electrolyte prepared by a special recipe. The voltage of the filament section of the battery must not be less than 2.2 volts; the anode, not less than 80 volts. The battery is placed in the bottom of the instrument.

The inclusion of the power supply to the transmitter is effected inside the instrument in the lower portion with a three-prong switch. The joint anode and filament lead has a break in which, outside the instrument, a disconnecting switch is installed.

After installing the battery in the bottom of the instrument, the outside disconnecting switch and the three-prong switch are connected.

## TESTING, RELEASE AND SIGNAL RECEPTION

The radio sounding apparatus is taken outdoors and its test run before release is conducted under the necessary conditions of ventilation and shielding against radiation. A comparison of the ordinates of registration with the calibration data is the last control operation before release.

The "Volna" radiosonde is sent aloft on balloon No 100, filled to a lifting force of 2,000 grams, which at a flying weight of the instrument of about 800 grams, provides a free lifting force of about 1,200 grams. The instrument is attached to the balloon with the aid of the antenna.

The moment of release is marked on the registration tape.

During flight, as was stated above, tuning on all of the signals of the radiosonde apparatus is done by rotation of the receiver hand knob. At the moment of tuning on the signal the tape is punctured by pressing the lever of the actuating mechanism. In order not to mix-up the points of various meteorological elements lying close to one another, they are marked by corresponding symbols. The definite inclusion order of the disks of variable and constant capacitive loads serves as a control to the succession of registration points corresponding to the meteorological elements measured.

Upon the cessation of signal reception from the radiosonde the reason for signal cessation is noted down.

## No 15. PROCESSING OF REGISTRATION TAPES OF THE "VOLNA" RADIOSONDE APPARATUS

The processing of the signals registered has the processing character of meteorograms. On the registration curves (Figure 180), certain points are selected, to which are referred: (1) points of moments of exposure prior to release, (2) points corresponding to the maximum altitude of ascent, (3) points of start and finish of inversion and isothermy, (4) points of sharp changes in temperature and humidity gradients. Besides, moments of entry and exit of the instrument into liquid (super-saturated) clouds are referred to certain points. They are identified on the registration by a sharp movement to the left of the points of maximum wavelength when entering the cloud and by a sharp movement to the right upon leaving the cloud.

After selection of special points on one curve, other points, synchronous to them, are selected on the other curves. Compared to the processing of meteorographs, the synchronization is easier due to the fact that the registration on the tape of the register is made on a right angle coordinate system. By drawing a straight line perpendicular to the minimum wavelength through the selected point the synchronous points will be obtained at the intersection of the straight line with the curves of the other elements and the control lines.

With the aid of the transparent rule described above the values of the ordinates of the selected points are then determined.

The rule is placed on the tape so that the minimum point on the tape will coincide with the zero line of the rule, and the maximum, with the line designated by the number 200. According to the lines of the rule, the value of the ordinate is measured and noted on the edge of the tape.

Then, using the calibration graph, the value of pressure, temperature and humidity is determined, according to the ordinates of the points.

In case small divergencies in the ordinates of the registration as compared to the calibration data have been found during the test run, corrections are introduced in the values of meteorological elements obtained in processing.

No of points

minutes

time

marks

release

minimum

maximum

exposure outdoors

minimum

maximum P = 990.4 mb

Figure 180. Registration of "Volna" Radiosonde signals.

Finally, altitudes are determined by the usual methods and a graph of the altitude distribution of meteorological elements is constructed.

The subsequent processing does not differ from the processing of sounding material obtained from the flight of comb radiosonde apparatus.

## No 16. ACCURACY OF RADIO SOUNDING. OUTLOOK FOR IMPROVEMENT OF METHOD.

The published data, characterizing the accuracy of measurement of that or this meteorological element by sounding, are rarely found to be capable of comparison with each other. In the majority of cases, separate errors of either one or another radiosonde apparatus and not the total error appearing as a result of all possible sources of errors in sounding is studied.

Therefore the work on the problem done by Soviet aerologists embracing its various sides appears not only to be valuable source material in the study of accuracy of sounding with Soviet radiosonde apparatus, but also as having great value in the correct solution of the problem in general.

The total error in measurements by the radiosonde method is the sum of the errors whose source is the radiosonde apparatus itself, as well as the errors of signal reception and the method of their reduction. Errors of the first type consist mainly of: (1) errors in the recorders of meteorological elements, (2) errors of the coding mechanism and transmitter, (3) errors of calibration and testing.

Errors of the second type include: (1) errors of the radio receiver, (2) errors in the fixation of signals by the operator or the registering device, (3) errors in the reduction of signals, connected with the graphic (in the majority of cases) method of registration reduction.

The errors of the recorders of elements have a different character and by their nature may be typed as either systematic or casual errors.

The systematic errors include those due to the inertia of the temperature and humidity recorders, as well as the effect of solar radiation on temperature readings. These errors may be eliminated by the introduction of corresponding corrections. There is a series of accidental errors, for example, due to friction in the transmission mechanism, deviation in the amount of inertia in various instruments, passing of the instrument through cloud layers and so forth. These are determined with difficulty.

The determination of the effect of inertia is made, as is known, by the determination of the coefficient of inertia $\alpha$, whose magnitude is inversely proportional to the square root of the ventilation value.

Besides the earlier mentioned values of the coefficient of intertia let us mention their values for recorders of several other radiosondes. Thus, for commutator radiosonde apparatus, for a velocity of ventilation of 5 meters per second, $\alpha$ = 15 - 17 sec; for a model 1940 radiosonde apparatus, $\alpha$ = 10 sec; for an aerostat radiosonde apparatus, $\alpha$ = 21 sec. For the temperature-sensitive condenser type of recorder in the German naval radiosonde apparatus as well as for the bimetallic receiver of the Finnish radiosonde apparatus, $\alpha$ is about equal to 15 seconds.

As we had seen (See Chapter III), the error due to inertia in the comb radiosonde apparatus on the average is not over about 1.0 degree.

The inertia of humidity receivers of the hair type in general is difficult to judge and, as is known, according to their size quite great, especially at low temperatures and small values of relative humidity.

Thus, for example, study of the Finnish radiosonde apparatus has shown a considerable dependence of the inertia coefficient on the temperature and an inconsequential dependence on ventilation. As was already shown, the coefficient of inertia has a value of 30 seconds at 20 degrees, 75 seconds at 0 degrees and reaches a value of 1,000 seconds at -30 degrees (see page 157).

In the measurement of humidity by the psychrometric method, the inertia will be tied-in with the inertia of dry and wet thermometers. As regards the coefficient of inertia of the electric hygrometer, its value, in general, must be less than the value of the coefficient of inertia of the usual hair hygrometer.

The inertia of the pressure recorder (hysteresis and elasticity effect) may play a role only in the reception of signals during descent of the radiosonde apparatus, which happens only in rare instances.

The study of the effects of solar radiation upon temperature recorders encounters a series of difficulties of a theoretical and experimental character. Evidently, the experimental path may give more quickly the answer to the question: what kind of effect is this and what corrections should be introduced?

The experimental investigations of the comb and commutator system radiosonde apparatus made by the Aerological Observatory of the GGO, have shown that with the usual ventilation for radiosonde apparatus (of about 5-6 meters per second) the effect of solar radiation may be telling only at considerable altitudes due to the decrease in the density of air and the increase in the intensity of solar radiation. The computations of A. A. Shepelevskiy have shown that a triple-shield wall for the ventilation shaft should fully eliminate the effects of solar radiation at high altitudes.

The studies of Vaysal on the Finnish radiosonde apparatus have shown that at a solar altitude of 20 to 40 degrees, the error due to radiation increases by about 2 degrees at an altitude of 13 kilometers to about 5 degrees at an altitude of 20 kilometers with a velocity of ventilation of 250 meters per minute. Evidently, in this case a considerable role is played by the comparatively small vertical velocity of the radiosonde apparatus.

Of the errors caused by the coding mechanism and the transmitter, the following are mentioned:

(1) influence of the condition of the combs on the accuracy of signal transmission by comb radiosonde apparatus

(2) influence of the non-regularity of the operation of the clock mechanism in radiosonde apparatus using the time-impulse method of coding;

(3) adverse outside influences upon the frequency of the transmitter in radiosonde apparatus using the frequency method of coding. These errors will have an accidental character.

For radiosonde apparatus using the frequency method of coding where the recorder acts upon the electric parameter of the radio transmitter circuit through a transmission, the error introduced by the detail of the coding circuit is systematic. For example, in the "Volna" radiosonde apparatus there is a capacitive load in the oscillating circuit and the observer marks off changes in the wave length $\lambda$ of the transmitted oscillations. Since $\lambda = 2\pi\sqrt{LC}$, the relative error in the determination of $\lambda$ is

$$\frac{\Delta}{\lambda} = \frac{\Delta C}{2C}$$ [page 319]

The accuracy of measurement, together with the errors of other types is then determined by the relation $\frac{\Delta C}{2C}$.

The influence of errors related to the inaccuracy of determination of sensitivity during calibration, to the inaccuracy of determination of the position of the indicators during the test run and the insufficient testing of the comb radiosonde apparatus, was studied by S. I. Sokolov. The influence of the first two errors is reflected to a great extent in the determination of altitudes according to the barometric formula and gives an error which increases according to the increase in altitude from 47 meters at an altitude of 1 kilometer to 315 meters at an altitude of 10 kilometers. The error due to insufficient exposure for temperature readings is ± 0.6 degree.

Errors of the second type, introduced by the reception of signals and their reduction have been little investigated.

For the time-impulse and number-impulse methods of coding, errors caused by inaccurate registration of instants of signal change or start of initial and working signals are systematic. For the frequency method, analogical errors will be related to the sensitivity of the radio receiver and to the errors in frequency fixation by the operator or the registering device.

Errors of processing of signal registration are identical for all types of registration in the case of the same scale of signal fixation.

For a comb radiosonde apparatus, according to the data of S. I. Sokolov, the magnitude of the error in the determination of temperature caused by the inaccuracy of registration of the instants of signal change amounts to ± 0.4 degree; this magnitude is attained by the error caused by the inaccuracy of the graphic method of reduction.

In Table 2, the maximum magnitudes of accidental errors in the determination of air temperature ($\Delta t$) and altitude ($\Delta z$) and ($\delta z$) for standard altitudes for the comb radiosonde apparatus are given.

Table 2

Maximum Errors $\Delta t$, $\Delta z$, $\delta z$ at Standard Altitudes for the Comb Radiosonde Apparatus

| | z km |
|---|---|
| $\Delta t^{o}$ C | |
| $\Delta z$ m | |
| $\delta z$ % | |

The table shows that the maximum error in the determination of temperature and altitude increases with altitude.

The relative error in the determination of altitude, with the exception of the low level, is maintained within 3 percent up to an altitude of 7 to 8 kilometers and then increases.

D. F. Masanov gives a computation for the expected error in the case of semi-automatic reception of signals of radiosonde apparatus using the frequency method of coding. If $\Delta f$ is the width of the frequency band of the resonance curve of the radio receiver $f_2 - f_1$, the range of frequency change for the entire scale of changes in the given elements from $A_2$ to $A_1$, then the expected error in the registration of the signal is expressed in the form

$$\Delta A = \Delta f \frac{A_2 - A_1}{f_2 - f_1} \qquad \text{[pp 320]}$$

Considering that the range of the measured pressure is 1,000 millibars (from 1050 to 50 millibars), the temperature, 100 degrees (from +30 to -70 degrees), the width of the frequency band of the radio receiver, 4 kilocycles, for the frequency scale from 25,300 to 23500 kilocycles, used in the "Volna" radiosonde apparatus, we will obtain an error in the pressure of ± 2 millibars and in temperature ± 0.2 degree.

The above discussion on probable errors of radio sounding shows the considerable complexity of the question and together with that gives an idea on how extremely difficult it is to demand a full comparison of the results of sounding.

Thus, comparative ascents of radiosondes on one balloon or simultaneously on two balloons conducted by the Main Geophysical Observatory show a divergence in the determination of temperature amounting to 4 degrees. This divergence may be even greater in size in the case of comparison of the results obtained during the ascent of radiosonde apparatus of several distinct systems.

An investigation of sources of errors and data of comparative soundings shows the great importance of further study of the accuracy of radio sounding and the improvement of pressure, temperature and humidity recorders.

The construction of barometric capsules for the measurement of pressure has reached considerable success at the present time. Thus, for example, in the radiosonde apparatus RZ-049, pressure capsules having practically no hysteresis or elastic after-effects are used; and in the construction of the pressure capsule, full thermo compensation is provided.

Together with the bimetallic inert temperature recorder thermistors and thermocondensers should be introduced. Research so far conducted points to several important characteristics: sufficient constancy in the calibration data, stability against outside influences, small inertia.

A more difficult problem is found in the improvement of the measurement of humidity. The use of psychrometric methods can hardly be recommended (according to the above stated reasons). As regards hygroscopic films, notwithstanding the great dependence of their readings on temperature and a decrease in accuracy at lower values of temperature, this method should be developed more in application to radiosonde apparatus. At the same time, experiments in the possible use of thermistors for the measurement of humidity are necessary.

Errors caused by inertia and radiation must be accounted for by their study and the introduction of corresponding corrections. On the other hand, a decrease in errors due to radiation should be sought by way of additional shielding of the receiver and painting with a white, highly reflective paint.

Further, the construction of the transmission mechanism in radiosonde must envisage a minimum of errors caused by the transmission of deformation of the recorders and the indicators.

In the measurement of meteorological elements it is desirable to have control points that permit the determination of absolute values of the elements by means of the character of signals received.

Signal registration should be semi-automatic or automatic.

In this there are a series of requirements whose attainment should result in a better method of radio sounding.

From this point of view, the new Soviet "Volna" radiosonde apparatus appears as a step forward in comparison with the comb apparatus used up to this time.

The "Volna" apparatus has no contacts in its scheme because the inclusion of the disks of variable and constant capacitive loads is made without contact with the aid of the original capacitive switch.

The recorders of meteorological elements are not overloaded with frictional contacts. This permits the use of a thinner bimetallic plate, which is important in the lessening of inertia.

For the ordinate minima on the pressure and temperature curves there is the possibility of removing the additional control points which do not depend on the radio communication channel because definite values of pressure and temperature taken for the points of bending from the calibration graph must correspond to the points of bending on the registration curves.

The instrument permits the determination of the thickness of layers of liquid (super-saturated) clouds.

A change in the distance of the limiting marks on the registration (from minimum to maximum), occurring as a result of interference, a drop in the filament voltage or a change in the connection of the antenna to the transmitter do not reflect on the results of measurement because the processing of the registration is done by measuring the ordinates relative to the extreme marks.

According to technical data of the "Volna" radiosonde apparatus the accuracy of measurement of pressure is ±2.5 millibars of temperature ±0.5 degree and humidity ± 5 percent.

By means of a high quality check (calibration) of the "Volna" radiosonde, a meticulous test run prior to ascent and an accurate reduction of material, it is possible to reach a considerably higher accuracy in radio sounding.

[End of Chapter VIII]

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